INDUSTRIAL SOLUTIONS LABORATORY

Company Information

Company Name	*Orano Federal Services*	**Date Submitted**	*11/29/2022*
Project Title	*Investigation of an Additive Manufacturing (3D Printing) Approach for Production of Impact Limiters for Transportation Casks for Used Nuclear Fuel* ***(ORANO_IMPACT)***	**Planned Starting Semester**	*Spring 2023*

Senior Design Project Description

Personnel

Typical teams will have 4-6 students, with engineering disciplines assigned based on the anticipated Scope of the Project.

Please provide your estimate of staffing in the below table. The Senior Design Committee will adjust as appropriate based on scope and discipline skills.

Discipline	Number	Discipline	Number
Mechanical	3-4	Electrical	0
Computer	0	Systems	1

Company and Project Overview:

Headquartered in Washington, D.C., Orano USA is a leading technology and services provider for used nuclear fuel management for existing and advanced reactors, decommissioning shutdown nuclear energy facilities, federal site cleanup and closure, and the sale of uranium, conversion, and enrichment services to the U.S. commercial and federal markets. With its parent company Orano, Orano USA has more than 50 years' experience securely transporting and storing used nuclear fuel (UNF) and has more than 30 years' experience in recycling UNF and decontaminating and dismantling nuclear facilities.

The Orano Federal Services business combines the capabilities, technologies, and resources from multiple Orano companies to serve the United States Department of Energy (DOE) and its subcontractors in all phases of the nuclear fuel cycle. Orano Federal Services provides key services as an active member in various projects that support DOE's five strategic services: Environmental Management (EM), Nuclear Energy (NE), Office of Science (SC), Office of Energy

Efficiency & Renewable Energy (EERE), and National Nuclear Security Administration (NNSA). Orano Federal Services currently is a contract team member of the following significant projects: the High Burnup (HBU) Demonstration Project; the Tank Operations Contract (TOC) at Hanford; the Advanced Reactor Demonstration Project (ARDP) providing support to multiple advanced reactors designated by DOE for support; the Advanced Research Projects Agency's Energy (ARPA-E) projects ONWARDS and CURIE; et al.

In anticipation of the need to transport UNF from operating and shutdown nuclear power plant sites to consent-based sited (CBS) consolidated interim storage facilities, disposal facilities, and/or conditioning/recycling facilities, a significant number of transportation casks will be needed. Per the Nuclear Regulatory Commission's (NRC) transportation regulations in Title 10 of the Code of Federal Regulations (CFR) Part 71 (i.e., 10CFR71), these casks will need to be designed to withstand hypothetical accident conditions (HAC) including a 30-foot free drop onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected. To withstand such a drop, these ~180-ton when loaded transportation casks are equipped with impact limiters on each end that are designed to absorb a significant amount of the energy of the drop event. Currently these impact limiters are very expensive to build (~$1M/impact limiter) as they are made of either rare materials (e.g., redwood) or complicated to hand-build aluminum honeycomb designs. The objective of this project is to investigate the use of an Additive Manufacturing, AM (aka 3D printing), approach to produce impact limiters for transportation casks for UNF that can be certified for performing their design requirements and ideally can produce these impact limiters at a fraction of the current cost of an impact limiter.

Project Requirements:

Orano will provide some details of impact limiter designs for its transportation cask systems that currently use redwood and aluminum honeycomb designs. Orano is currently fabricating a set of redwood-based impact limiters for its HBU demonstration cask (a TN32B cask) at a significant cost and has also built a set of aluminum honeycomb impact limiters at great difficulty and expense for its MP197HB transportation cask. To reduce the cost and potential fabrication difficulties associated with these types of impact limiters, Orano is interested in establishing if advances in AM (3D printing) can perform the printing of these types of impact limiters at reduced costs, while at the same time meeting design requirements to meet the HAC of 10CFR71. Orano is hoping that some of UNCC's motorsports (NASCAR) experience potentially with the SAFER Barriers can be utilized to support this activity.

This project is a follow-up to a portion of two previous senior design projects performed at UNCC in 2017 and 2020 and documented in a Waste Management paper[1] and an American Nuclear

[1] S. Bader, M. Smith, "Alternative Impact Limiter Designs for Used/Spent Nuclear Fuel Transportation Casks," (poster), Waste Management Symposium 2019.

Society (ANS) paper[2]. This project is intended to re-examine the AM approaches to producing impact limiters through one or more of the following considerations (and others not potentially identified here):

- Complete AM (metal) of an impact limiter
- Partial AM (metal) of portions of an impact limiter that can be assembled into a complete impact limiter
- Complete AM of an impact limiter using alternative materials
- Partial AM of portions of an impact limiter using alternative materials
- Alternative impact limiter design that can be more easily fabricated by AM (e.g., superplastic forming of aluminum which involves laser welding of sheets of aluminum then pressuring to form a honeycomb like interior)
- Alternative impact limiter materials (e.g., syntactic foam, liquid crystal elastomer) and/or design

For impact limiters different from the current designs, materials testing will need to be identified to ensure design requirements can be met especially if AM materials are utilized and if able, the testing should be performed. In addition, some modeling of the HAC drop event could be performed with ANSYS or similar modeling software to identify viable impact limiter designs and materials.

The project would begin with a review of the previous AM experience on this topic determining which AM process(s) may be the optimal for production of these large pieces of equipment. This activity may include utilizing UNCC's AM devices to produce a small-scaled demonstration print that may include segmented printing and subsequent assembly (e.g., welding). In addition, the project team would identify the impact limiter designs to be simulated and the requirements the design needs to meet for the 10CFR71 HAC drop event.

Once an AM production approach(s) has been selected (see above list of bullets), identify potential fabricators capable of producing the impact limiters and identify any testing needed to verify the AM fabricated components and utilized materials (stainless steel, aluminum, inconel, etc.) are demonstratable towards performing the necessary design requirements. This may include numerical modeling of the 10CFR71 HAC 30 ft drop event to verify the design and utilized materials produce likely acceptable results. This may be a crude model simply designed to dismiss obsolete designs and unacceptable materials.

With an AM production approach(s) selected and potential materials and design established, an estimate of the production cost and production duration should be assessed. In addition, requirements for each step of the fabrication process should be established, which includes potential testing requirements.

[2] M. Smith, S. Bader, B. Crotts, Y. Sireli, "Conceptual Design of Additive Manufacturing Based Honeycomb Geometry for Impact Limiters," Transactions of the ANS, June 2022.

Ultimately, a whole alternative fabrication process should be identified with cost and production time estimates and compared to current fabrication, cost, and duration estimates.

Expected Deliverables/Results:

- A report documenting an optimized approach to AM of impact limiters for transportation casks for UNF capable of protecting the package during a 10CFR71 HAC 30-ft drop event
- A model (e.g., artistic rendering) of the proposed AM impact limiters and the steps to completing the impact limiters
- A cost and production duration assessment of the proposed AM impact limiters
- Assessment of alternative impact limiter design materials
- Potentially a small scale UNCC AM printed set of impact limiters produced using the optimized approach or something similar
- Potential numerical model of the proposed AM impact limiter design under the 10CFR71 HAC 30-ft drop event

Disposition of Deliverables at the End of the Project:

Students are graded based on their display and presentation of their team's work product. It is mandatory that they exhibit at the Expo, so if the work product was tested at the supporter's location, it must be returned to campus for the Expo. After the expo, the team and supporter should arrange the handover of the work product to the industry supporter. This handover must be concluded within 7 days of the Expo.

List here any specific skills, requirements, specific courses, knowledge needed or suggested (If none please state none):

- Ideally some knowledge of ANSYS or similar software analysis for examining structural impacts as a result of a drop event